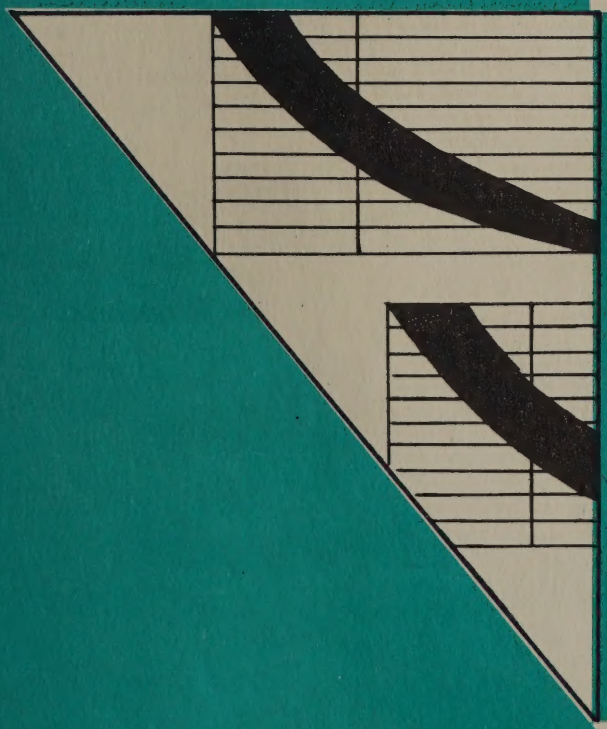
Wesley Moody

STATE OF NEW YORK

DEPARTMENT OF PUBLIC WORKS



CONSTRUCTION OF FOUNDATION COURSES FOR CONCRETE PAVEMENT

ENGINEERING RESEARCH SERIES NO. TM 58-3

TECHNICAL MANUAL

JUNE 1958

CONSTRUCTION OF FOUNDATION COURSES FOR CONCRETE PAVEMENTS

STATE OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SOIL MECHANICS

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PREFACE

The information in this Manual has been prepared for the use of Engineers of the New York State Department of Public Works engaged in inspection or supervision of construction projects. The data are not a part of the Specifications; nor do they form a part of any contract. Rather, they are to assist the Engineers in the application of the Specifications as written.

The Specifications are the final control in the Engineer-Contractor relation. This Manual has been based upon the Specification requirements, and is to be considered as an expansion of them. In no way can this Manual be used so as to oppose the requirements and objectives of the Specifications.

Particular attention is called to the fact that special specifications may be adopted from time to time for particular projects. These special specifications will be shown in the Proposal or in the form of notes on the plans. They may alter features of work from the methods indicated in this Manual. It shall be the responsibility of the Engineer-in-Charge to acquaint all inspectors with any such special requirements.

The Specifications in general specify either the results to be obtained or the methods to be used, although, in some instances, they specify both result and method. Unless the Specifications definitely specify a method, Contractors must be permitted to use alternate methods of their own devising as long as those methods produce the required results. Where there is a choice of method, however, the inspectors should attempt to further the procedure preferred by the Department, as far as they are able, within the Specifications and contract agreement.

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INTRODUCTION

Nationwide studies of the effect of high traffic volumes and loads on our existing highway system conclusively prove the importance of adequate foundation courses. Unless proper attention is given to the selection of materials for this foundation and to construction procedures, concrete pavements may fault or pump at the joints and slab cracking may develop.

The foundation course must distribute the load over the subgrade soil and be sufficiently strong within itself to carry the loads imposed through the concrete slab. Also, it must be of such a gradation from coarse to fine as to prevent the subgrade soil from working up and infiltrating into it. Further, it must be so graded that it will not shift nor migrate under the slab with subsequent loss of material either through the joints or from beneath the edges. It is also essential that foundation course materials be composed of sound, durable, physically stable aggregates and fractions, such that the particles do not break down or disintegrate under the action of rolling equipment, subsequent traffic load and freezing cycles sufficiently to impair the performance of the course.

The materials to be used for foundation courses beneath concrete pavement and the construction procedures to be followed in the placement of these materials are described by the Department's Specifications, Item 39A, Foundation Course-Granular Material-Type A; Item 39, Foundation Course Granular Material; and Item 8, Preparing Fine Grade. A scarcity of sources of acceptable Item 39A granular materials in some areas of New York State has resulted in the two-layer design of foundation course. This generally provides for a six-inch layer of Item 39 to be placed as a base beneath a second six-inch layer of Item 39A material, thus using less than 50 percent of "select" material in those areas where Item 39A quality material is scarce.

ITEM 39A, FOUNDATION COURSE-GRANULAR MATERIAL-TYPE A

Quotations are from Specification, Item 39A, Foundation Course-Granular Material-Type A, Pages 292-294, D.P.W. Specs., January 2, 1957.

MATERIAL

Quality

"All granular material acceptable for this item shall be of hard, durable, stone or slag and well graded from coarse to fine."

In judging the quality of gravel samples, consideration is given to the lithology of the material, its origin and the geologic method by which it was deposited. Magnesium sulphate soundness tests are performed in accordance with the procedure specified for Crushed Gravel (Pages 86-88 Specs.). Soundness is judged by the percent loss after 4 cycles. The maximum percent loss at 4 cycles, by weight, shall be 20.

Gradation

"The particles shall be of a maximum diameter equal to two-thirds the thickness of the compacted layer of the foundation course under construction but shall not exceed such size as will pass through a 4 inch square hole; 30 percent to 65 percent, by weight, shall pass the 1/4 inch square sieve, and not more than 10 percent, by weight, shall pass a No. 200 mesh sieve. The particles passing a No. 40 mesh sieve shall have a maximum Plasticity Index of 3.

"Should, at any time during the work and for any reason, the material fail to maintain suitable proportions of coarse and fine particles, the Contractor shall, by the addition of selected material and/or satisfactory manipulation, produce a material meeting the above requirements."

The gradation requirements are specific for the 4-inch, the 1/4-inch and the No. 200 sieve. Judgment of - "suitable proportions of coarse and fine particles" - is based on the shape of the grain-size distribution curve, with particular attention given to the ratio of the percent passing the No. 200 to the percent passing the No. 40. If this ratio exceeds 1/2, further examinations are made.

General Comments on Materials

Inasmuch as the materials within any particular gravel deposit were laid down by the same sequence of geologic events, it is

possible to assume that the samples tested are fairly representative of the quality of the gravel within the entire deposit. However, due to the irregularities of stratification and bedding, the samples tested may not be representative of the gradation of the material throughout the entire deposit.

The Department is buying a particular product as defined by the Specifications. Approval of samples by the Bureau of Soil Mechanics constitutes approval of the quality of material within the sampled deposit.

The Contractor must select a production procedure that assures the delivery of properly graded material to the job, and on-the-job inspection and tests must be performed by District forces to determine the acceptability of gradation. The above quote, second paragraph under Gradation, provides authority for on-the-job approval of gradation.

Field Analysis

In order to ascertain the gradation of the foundation course material being placed on the subgrade, it is recommended that the following test procedure be employed:

> A test sample of approximately 50 pounds shall be taken of the granular material as dumped on the subgrade, before the blade grader or bulldozer has had an opportunity to spread the material. One sample shall be taken of approximately every 500 cubic yards, if the gradations are uniform and acceptable. More frequent testing shall be done if it appears that there is a wide variation in gradation, so that it can be certain that acceptable material is being placed on the subgrade or in areas called for on the plans.
>
> The field control can best be gauged by the use of the 1/4-inch sieve, and the test can be run on the sample, as taken, without prior drying. The sample is weighed, run through a 1/4-inch sieve, and the percentage retained on the 1/4-inch sieve is determined by dividing the weight retained on the 1/4-inch sieve by the total weight of sample. This procedure will ascertain whether the granular material is meeting the 1/4-inch requirement.
>
> The Bureau's experience indicates that, in the majority of instances, if the percentage passing the 1/4-inch sieve does not exceed 50 percent, it is probable that the percentage passing the No. 200 sieve will be less than 10 percent. If the percentage passing the 1/4-inch sieve exceeds 50 percent, a sample should be taken and a gradation test run in the usual manner to determine if the material meets the Specifications.

Granular material having greater than 10 percent passing the No. 200 sieve will be rather dirty. A simple field test is to make a ball of moist minus 1/4-inch material and roll it in the palm of your hand. If the mixture leaves a muddy condition in the palm, after drying, then the material is probably too dirty. If the palm is only slightly stained, material might be of acceptable gradation. However, it is suggested that periodic samples be submitted to the District laboratory, if there is any doubt as to whether the material is exceeding the 10 percent requirement of the No. 200 sieve.

MANIPULATION

Placing

"No segregation of large or fine particles will be allowed, but the material as spread shall be well graded with no pockets of fine material."

It is acknowledged that the present procedure followed in placing materials - dumping and spreading with blade graders - results in considerable non-uniformity. It is believed, however, that this procedure can be accepted, provided attention is given to - "no pockets of fine material." Where such pockets occur they should be removed and replaced with well-graded material.

"The thickness of the layer shall have a maximum depth of 6 inches after compaction."

The approximate loose thickness should not exceed 7-1/4 inches, to give a compacted depth of six inches.

"This course shall not be laid in excess of 500 linear feet without being compacted."

The reasons for this are to discourage construction traffic on the loose granular layer with the resulting decrease in the possibility of the subgrade becoming churned up into the foundation course and also to immediately "tighten up" the course to prevent the softening of the subgrade due to rains.

Rolling

"Water shall be added in such amounts as the Engineer may consider necessary to secure satisfactory compaction. When the moisture content of the layer is within the limits for proper compaction, the entire surface shall be rolled with a pneumatic tired roller, having an operating weight of between 1,000 and 2,500 pounds per tire, or a smooth wheel roller, having a minimum weight of 10 tons. Each portion of the layer shall be covered by a minimum of 8 passes of the roller."

The object of sufficient rolling at the proper moisture content and with the correct equipment is to obtain uniformity of compaction throughout the layer. Uniform compaction should be obtained if the conditions of moisture content, number of roller passes, layer thickness and weight of roller are correct. The minimum number of passes of the 10-ton smooth wheel steel roller or the pneumatic tired rollers, having a minimum of nine tires with an operating weight of 1,000 to 2,500 pounds per tire, has been set at 8.

The presence of sufficient water greatly aids the compaction process. Gravels should appear fairly wet when rolled; if not, adequate water must be added. Adequate moisture is very important in the compaction of granular materials.

New equipment is continually being developed, mainly in the form of grid-type steel rollers, 30-ton (or heavier) pneumatic rollers or vibratory rollers of the wheel or pad type. These newer units may be able to do a satisfactory job of obtaining uniform and sufficient compaction on the foundation course layer, with a fewer number of passes. If satisfactory uniform compaction can be obtained, after thorough evaluation of the equipment by the District Soils Engineer, permission may be granted to decrease the specified number of passes.

> "After compaction, the top surface of this course shall not extend above, nor be greater than 3/4 inch below, true grade or cross section. Any depressions or holes shall be filled with this same material and the surface rerolled. In all cases, this foundation course must be so thoroughly compacted that it will not weave under the roller."

"Thoroughly compacted" can be judged best by observing the action of the roller. If the course has not been sufficiently densified with the specified minimum amount of rolling, additional passes will be required. Unstable local areas may be due to excessive fines; if so, these should be dug out and replaced with gravel. The compactness of each layer must be inspected and approved by the Engineer before the next layer is placed.

> "In limited areas where the use of a roller is impractical, approved mechanical tampers shall be used to compact the material."

This is important adjacent to structures. "Mechanical Tampers" may include special vibrators, or heavy mechanical impact rammers. Suitable equipment for this work is specified on Page 201 of the 1957 Specifications. Hand tampers are not permitted.

It had been quite common for Contractors to leave the rough gravel surface slightly higher than the ultimate top of foundation course. At the initiation of fine grading operations, the upper

two to four inches of the foundation course were scarified. After further manipulation and the removal of the larger gravel (often everything above two inches), this loose material would form the upper crust of the foundation course. In addition to being loose, this surface material would contain fines greatly in excess of the allowable maximum of 10 percent passing the No. 200 sieve.

Another common practice had been to loosen the upper part of the foundation course by the action of a subgrading machine. Voids and surface irregularities that developed during this operation were filled by material from the fine grader's screed, which generally consisted of only the finer portions of the foundation course containing an excessive amount of material passing the No. 200 sieve.

Obviously, having loose, fine material at the top of the foundation course, directly beneath the pavement is a very undesirable condition. Actually, it is in this area that the highest quality, most compact foundation course material is needed.

In order to alleviate this poor construction practice, the 1957 Specifications specifically state that, "After compaction the top surface of the foundation course shall not extend above nor be greater than 3/4 inch below, true grade and cross section."

EFFECTS OF TRAFFIC

In a great many cases, the foundation course is subjected to traffic, either as a haul-road for the Contractor's equipment or for the maintenance of normal traffic. Such traffic can very easily destroy the acceptability of the foundation course as follows:

1. The weight of the vehicles may be such as to actually cause a failure of the subgrade material with subsequent rutting and displacement. Such failures normally result in the mixing of the subgrade material with the foundation course, consequently, modifying its gradation. In such cases, those areas showing instability should be excavated to the full depth of the foundation course, replaced with gravel and rerolled. Coverage is provided in the Specification for such treatment as follows:

"Should the subgrade or foundation course become churned-up into, or mixed with, the foundation course Type A through any reason whatsoever, the Contractor shall, at his own expense, remove such mixture of subgrade or foundation course and replace with foundation course Type A material acceptable for this item."

2. The gradation of the material in the upper portion of the foundation course may be materially

modified by spillage from hauling equipment or by the deposit of fine material from construction traffic usage. The increase in fine material in the upper layer of the foundation course, in such instances, is extremely undesirable. Before fine grading operations are initiated and where the foundation course has been subjected to such use, the gradation of the upper crust of the foundation course must be checked to determine whether or not it meets Specifications in its final condition. The approximate field gradation check method described on Page 3 may be used to initially spot check the final gradation condition of the foundation course.

In those instances where the project is progressed by stage construction or when the foundation course is permitted to lay open over the winter months, modification in the compactness of the material can occur due to climatic conditions only. On such projects, the surface should be thoroughly rolled prior to the initiation of fine grading operations and any soft spots that are detected should be corrected by excavation and replacement.

Any areas where gradation check tests indicate that the final foundation course gradation no longer conforms to the Specification requirements, because of such practice, the unsuitable foundation course material should be removed and replaced with properly compacted suitable material at the Contractor's expense. The foundation course material must conform to the Specification requirements at the time the pavement is placed.

ITEM 39 - FOUNDATION COURSE GRANULAR MATERIAL

Quotations are from Specification, Item 39 - Foundation Course-Granular Material, Pages 291-292, D.P.W. Specs., January 2, 1957.

MATERIAL

Quality

"Under this Item, the Contractor shall furnish and place a foundation course of Run-of-Bank Gravel or Sand, Slag, Wash Quarry Stone, Stone Screenings or other acceptable granular material."

There are no soundness tests required for samples of this type of material, but the Engineer should obtain the best material possible for this item, under the requirements of the Specifications.

Gradation

"The particles shall be of such size as will pass through a 4-inch square hole; not more than 70 percent by weight shall pass the No. 40 mesh sieve and not more than 10 percent by weight shall pass the No. 200 mesh sieve."

General Comments on Materials

The specified controlling factor of this material is the gradation. The gradation requirements of the Specifications should be rigidly enforced to obtain the best possible foundation course.

Field Analysis

The gradation of the materials being placed for this item should be thoroughly and frequently checked to assure that such materials conform to the requirements of the Specifications.

MANIPULATION

Placing

"The material shall be spread in such depths that the thickness of any layer after compaction shall have a maximum of 8 inches."

The material should be so spread that the surface after compaction is uniform and smooth.

"After compaction, the course shall be true to grade and cross-section, and depressions shall be eliminated by the use of additional granular material."

The same care should be exercised in the placement and subsequent rolling of this material as is used for Item 39A, as it forms a part of the pavement foundation structure.

Rolling

"Water shall be added in such amounts as the Engineer may consider necessary to secure satisfactory compaction. When the moisture content of the layer is within the limits for proper compaction, the entire surface shall be rolled with a pneumatic tired roller having an operating weight of between 1,000 and 2,500 pounds per tire, or a smooth wheel roller having a minimum weight of 10 tons. Each portion of the layer shall be covered by a minimum of 8 passes of the roller."

Sufficient rolling at the proper moisture content with adequate equipment is absolutely necessary to obtain a uniformly well compacted foundation course. Uniform compaction will be obtained if the requirements of optimum moisture content, sufficient number of roller passes, proper layer thickness and adequate weight of roller are met. The minimum number of passes of the 10-ton smooth wheel roller or the pneumatic tired roller, having a minimum of nine tires with an operating weight of 1,000 to 2,500 pounds per tire, has been set at 8.

New equipment is continually being developed, mainly in the form of grid-type steel rollers, 30-ton or heavier pneumatic rollers or vibratory rollers of the wheel or pad type. These newer units may be able to do a satisfactory job of obtaining uniform adequate compaction of the foundation course layer, with a fewer number of passes. If satisfactory uniform compaction can be obtained, after thorough evaluation of the equipment by the District Soils Engineer, permission may be granted to decrease the specified number of passes.

"After compaction, the course shall be true to grade and cross-section, and any depressions shall be eliminated by the use of additional granular material. In all cases, the foundation course must be so thoroughly compacted that it will not weave under the roller."

"Thoroughly compacted" can be judged best by observing the action of the roller. If the course has not been sufficiently densified with the minimum required amount of rolling, additional passes will be necessary. Any unstable local areas should be removed and replaced with suitable, well compacted material. The condition of each layer must be inspected and approved before the next layer is placed.

"In limited areas where the use of a roller is impractical, approved mechanical tampers shall be used to compact the material."

This is important adjacent to structures. "Mechanical Tampers" may include special vibrators, or heavy mechanical impact rammers. Suitable equipment for this work is specified on Page 201 of the 1957 Specifications. Hand tampers are not permitted.

EFFECTS OF TRAFFIC

In a great many cases, the foundation course is subjected to traffic, either as a haul-road for the Contractor's equipment or for the maintenance of normal traffic. Such traffic can sometimes destroy the acceptability of the foundation course.

The weight of the vehicles may be such as to actually cause a failure of the subgrade material with subsequent rutting and displacement. Such failures normally result in the mixing of the subgrade material with the foundation course, consequently, modifying its gradation. In such cases, those areas showing unsuitability and instability should be excavated to the full depth of the foundation course, replaced with suitable material for this item and rerolled.

In those instances where the project is progressed by stage construction or when the foundation course is permitted to lay open over the winter months, modification in the compactness of the material can occur due to climatic conditions only. On such projects, the surface should be thoroughly rolled prior to the initiation of fine grading operations and any soft spots that are detected should be corrected by excavation and replacement.

ITEM 8 - PREPARING FINE GRADE

Reference: D.P.W. Spec.
January 2, 1957.

The preparation of the surface on which a concrete pavement rests involves two pay items: (1) Foundation Course, and (2) Preparing Fine Grade. In general terms, it is the intent of these items that the pavement shall rest upon thoroughly compacted material conforming to the gradation quality requirements of Item 39A. Careful attention must be given, not only to the placement of the foundation course material, but also to the construction procedure followed in the preparation of fine grade. Lack of attention to this latter factor may leave the material at the top surface of the foundation course in a loose condition and of a gradation that is excessive in fines.

After compaction, the top surface of the foundation course shall not extend above nor be greater than 3/4-inch below true grade and cross-section. This maximum dimension of 3/4 inch is a limiting one. It limits the amount of material to be added after the foundation course has been installed, and every effort should be used to keep this quantity at a minimum. It is, however, liberal enough to prevent the necessity of ripping up the foundation course to remove stones that may project above the foundation course surface.

The 1957 Specifications further state: "All hollows and depressions which develop under rolling shall be filled with acceptable granular material and shall again be rolled. Granular material used to fill the depressions shall consist of approved hard, durable particles 100 percent of which shall pass a 1/2-inch and not more than 5 percent of which shall pass a No. 200 sieve."

The intent of this method of Preparing Fine Grade is to eliminate the built-in-condition of a loose uncompacted layer, excessively high in fines, directly beneath the pavement slab.

The 1957 Specifications call for finish rolling within the forms to be done with a 10-ton roller. The increased weight has considerable advantage. Water should be added to facilitate compaction. A final check should be made of the prepared fine grade for soft spots - correction should be by additional rolling, or removal, replacement and recompaction.

The transverse joint assemblies and the longitudinal forms must be placed on a compact foundation; the Contractor must adopt a work procedure that will provide the desired condition.

APPENDIX

The following pictures illustrate some of the practices allowed in preparation of fine grade under the 1951 Specifications and which are no longer acceptable under the January 1957 Specifications.

FIGURE 1

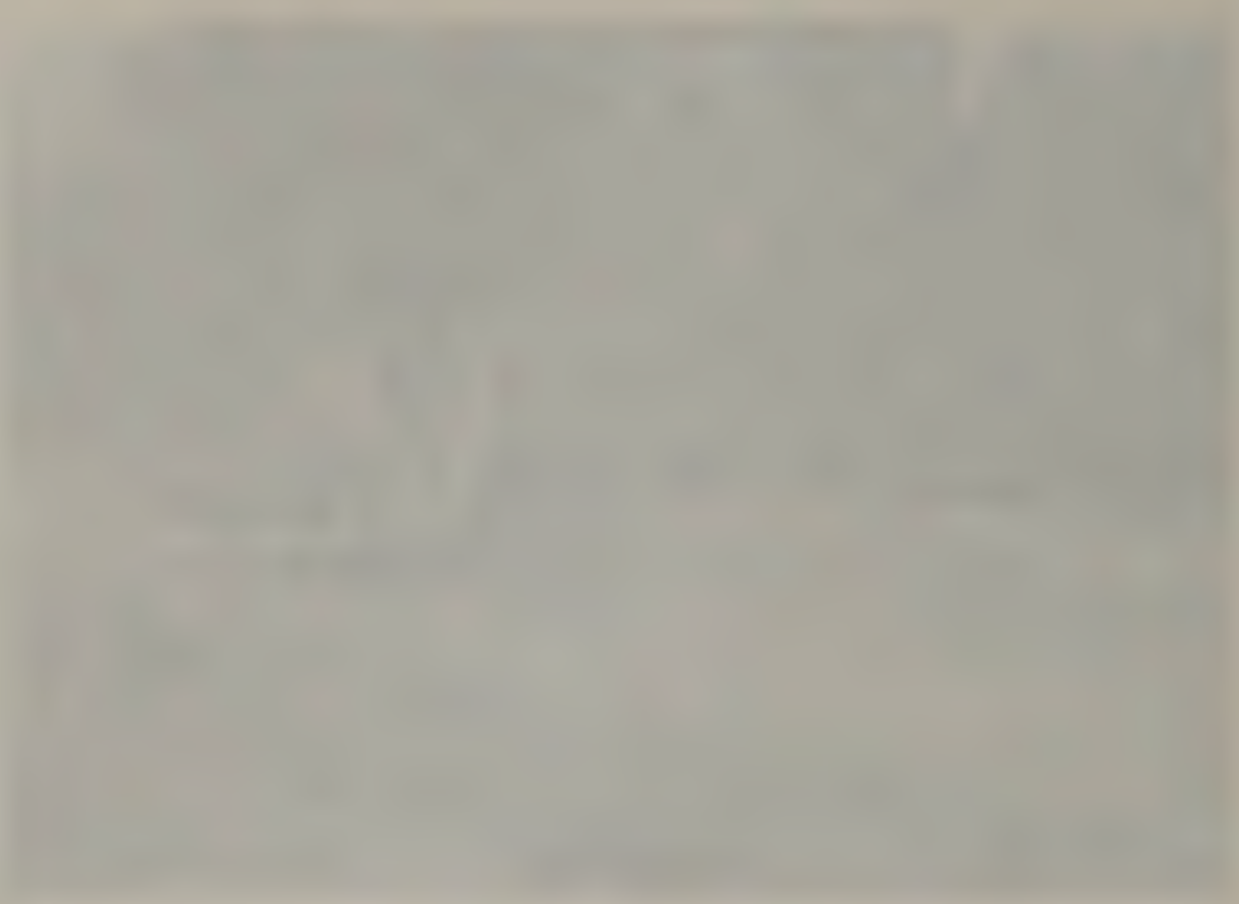
Photograph showing condition of scarified foundation course. Gravel surface course was initially placed above ultimate top of foundation course grade and during the fine grading operation, the upper two to four inches were scarified. This caused the situation shown, whereby loose material formed the upper portion of the foundation course and, in addition to being loose, probably contained fines greatly in excess of the allowable 10 percent passing the No. 200 sieve. Such practice is neither necessary nor permitted under the 1957 Specifications.

FIGURE 2

Photograph showing condition of loose surface area of foundation course caused by the action of a fine-grading machine. Voids and surface irregularities that developed during this operation were filled by material from the fine grader's screed and generally consisted of only the finer portions of the foundation course containing an excessive amount of material passing the No. 200 sieve.

FIGURE 3

Photograph showing finish rolling within the forms by a five-ton roller. The 1957 Specifications specify a self-propelled roller weighing not less than 10 tons which should result in a much more stable and uniformly finished surface upon which to place the pavement.



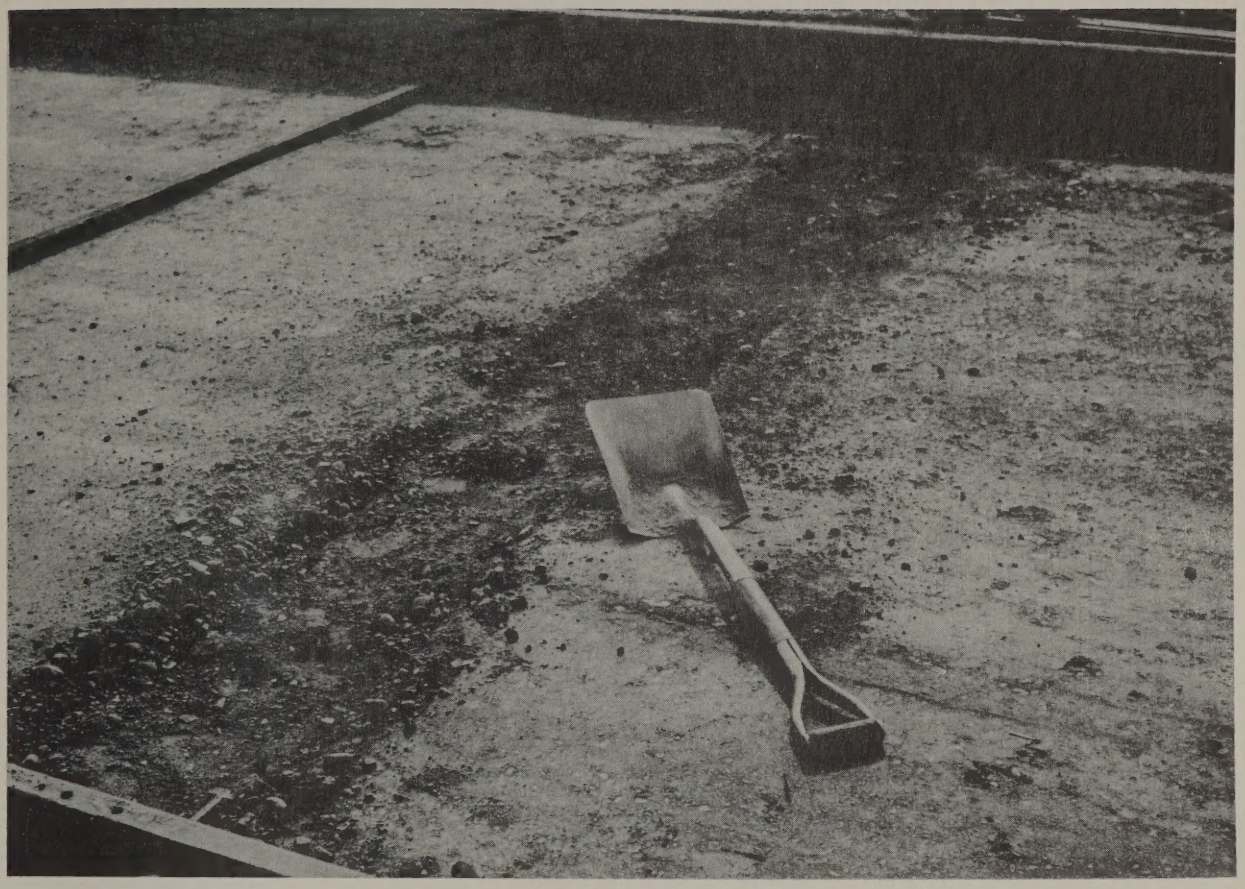
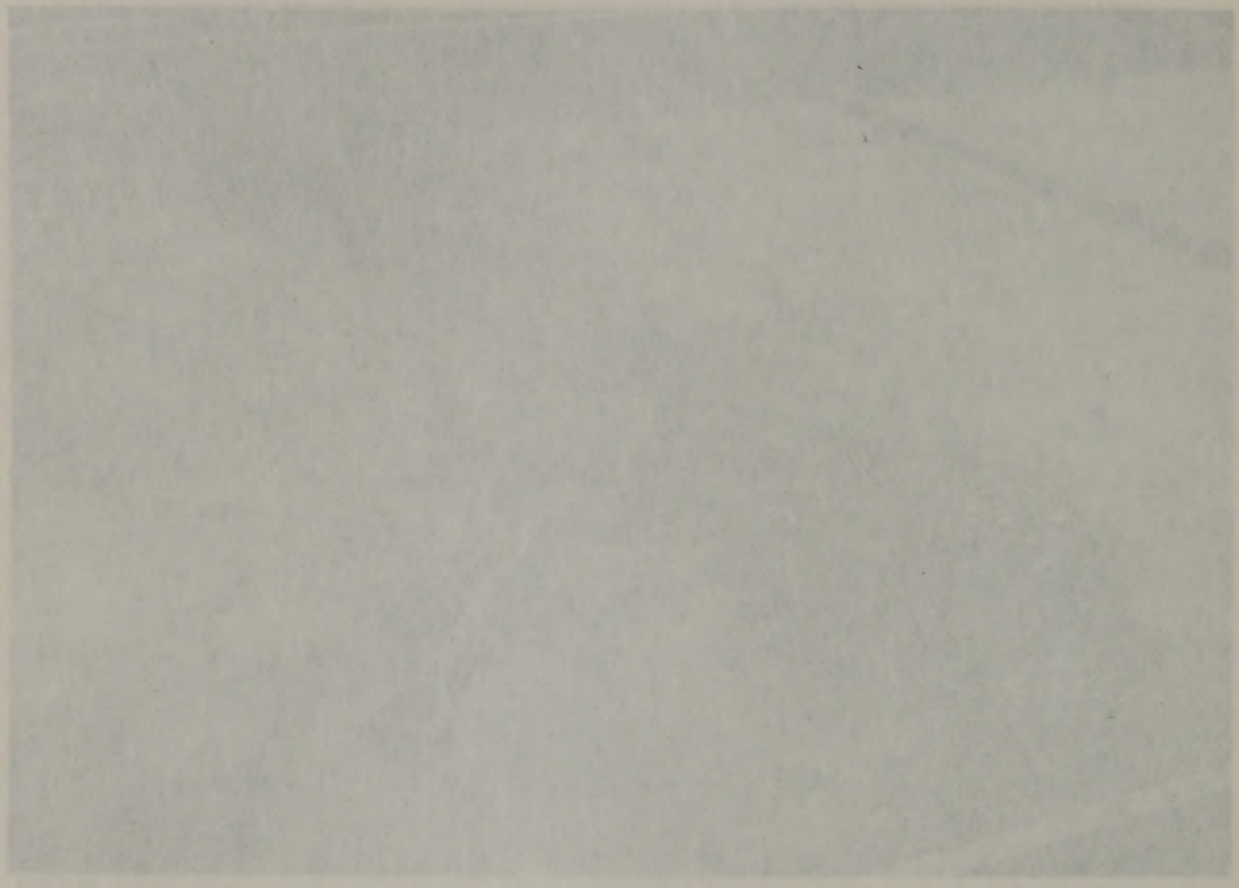


FIGURE 4

The above picture shows a bad practice that has long been prevalent in joint installations. A loose foundation course condition in such critical areas invites post-construction troubles.

Page 162 of the January 2, 1957 Specifications, under "Pavement Concrete", states: "Trenching will not be permitted." As will be noted above, the previously compacted foundation course has been loosened and badly raveled in the area where it should be particularly well compacted.

The transverse joint assemblies and the longitudinal forms must be placed on a compact foundation; the Contractor must adopt a work procedure that will provide the desired and specified condition.



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